Study of the combined effect of mechanical stress and high temperature on the switching field of submicron particles permilloy

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Nowadays it is known that high density of data magnetic recording is able to be achieved using Heat Assisted Magnetic Recording (HAMR) on a separately located ordered particles. The general idea of this method is decreasing of coercitivity of ferromagnetic particles by heating each particle using pulse laser [1]. So investigation of influence of high temperatures on ferromagnetic particles switching field is in great interest now. On the other hand, rapidly developing scientific direction called "straintronics", that study effects in solid state materials caused by mechanical stress, predicts significant decrease of energy consumption for straintronic devices as compared with nowadays technologies. Considering this, in our work we tried to combine high temperature and mechanical strain influence on permalloy microparticles. The main problem is to find out how the simultaneous effect of heating and mechanical stress on the switching field of permalloy microparticles.

For that reason samples with submicron permalloy particles on silica substrate were prepared using scanning-probe lithography [2]. At first, investigations of only high temperature on switching field were carried out. For this reason sample without induced mechanical strain was manufactured. Another sample was manufactured as it described in paper [3]. Permalloy with negative magnetostriction (Ni 79%, Fe 16%, Mo 4%) was deposited on the surface of bended substrate through the lithography mask. Permalloy film was deposited 50 nm thick. After that substrate was straightened and compression strain was induced in the particles. On the single substrate two arrays of the particles were manufactured for the reason to research arrays with perpendicular direction of the long axises to the direction of compression. Lateral size of the particles was about 1350×350 nm (Fig. 1).

Experiments were carried out on Solver VH (NT-MDT) scanning probe microscope. First of all, all particles in array were magnetized in external magnetic field to the one of the directions along their long axis. After that, in vacuum state particles were heated up to the necessary temperature and cooled down in external magnetic field of the opposite direction. At the next step, using magnetic-force microscopy, we counted the particles that changed the direction of their magnetization. Cycle repeated for the constant temperature, increasing the magnetic field until all particles switched.

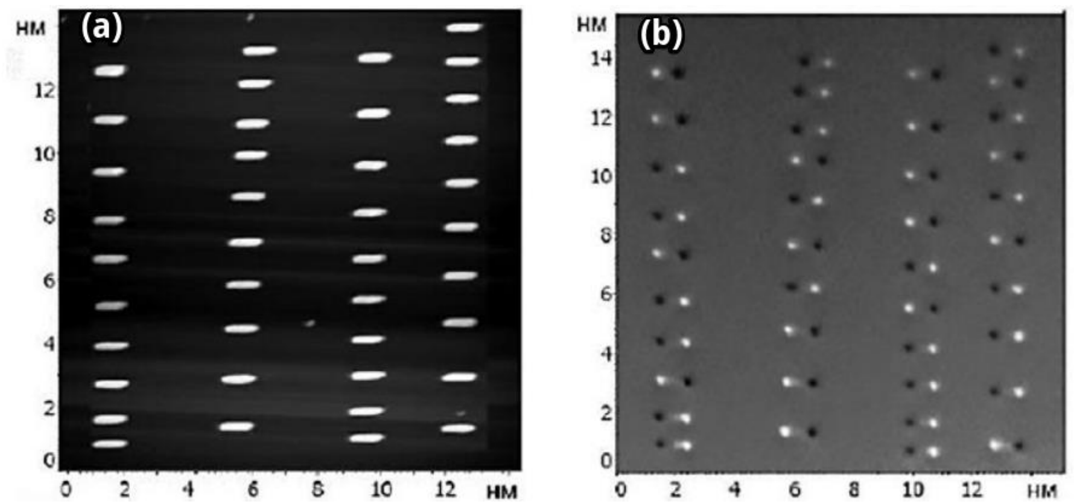

Figure 1. (a) Atomic-force microscopy image of topography of strained permalloy array particles, (b) Magnetic-force microscopy image of the same particles.

During researching the sample without induced strain, temperature dependence of the switching field graphs was built. Temperature range was from 300 K to 800 K. After analysis of the graphs it was shown that field that is necessary to switch the magnetisation of all particles decrease from 700 Oe at 300 K to 180 Oe at 800 K [4].

Stressed sample was studied for both orientations of long particle axises relatively to induced strain direction at a temperature of 100°C (373 K) before heating at 300°C (673 K) and after heating. Previously, it was shown that all kind of strain disappear in permalloy particles of this composition after heating at 300°C.

As a result, of further researches magnetic field dependence of number of switched particles was built at 100 °C before heating and after heating for both of orientations of the particles. So it was shown, that induced mechanical strain changes the switching field of the permalloy particles on about 9 Oe. This change may increase or decrease switching field of the particles depending on direction of the long axises relatively to the direction of strain and magnetostriction sign.

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